

Monsanto Company (formerly Agracetus, Inc.)

Biopolymers to Give Cotton Fibers Synthetic-Like Qualities

In 1994, researchers in the U.S. cotton industry believed that genetic engineering was the key to improving cotton fibers. For more than 100 years, U.S. scientists have used breeding techniques and biological innovations to improve the quality of the domestic cotton crop. By the early 1990s, however, advances in chemistry and manufacturing techniques enabled synthetic fibers to surpass cotton in characteristics such as strength, wrinkle resistance, and ability to bind with dyes. Key players in the U.S. cotton industry knew that, in order to compete with largely foreign-made synthetic fabrics, they would have to make significant research advances within a short period of time. The potential to lose cotton sales to synthetic fabrics was projected at more than \$200 million annually until at least 2005, given normal market growth.

One major focus of this research was to incorporate biopolymers into cotton plants. As of 1994, there were no viable methods for inserting these biologically derived substances into the cotton in a way that would allow the fiber to take on synthetic characteristics while retaining its natural ability to feel cool in the summer and warm in the winter. If biopolymers could be inserted successfully, however, cotton plants would gain the favorable qualities of synthetic materials without losing the qualities of pure cotton. With cost-shared funding from the Advanced Technology Program (ATP), Agracetus, Inc., pursued an aggressive research project from 1995 to 1998 to incorporate biopolymers into cotton fiber. By the end of the ATP-funded project, the research had advanced the state of knowledge of biopolymers several years ahead of where it would have been otherwise. Despite the added knowledge, Agracetus researchers were unable to reach a high enough concentration of the biopolymer to develop a competitive fiber.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

No Stars

Research and data for Status Report 94-01-0074 were collected during December 2002 - January 2003.

Cotton Losing Its Competitive Advantage

Though U.S.-grown cotton was the premier natural textile fiber as of 1994, the industry faced substantial challenges from synthetic fabrics and commodity pricing; the cotton industry simply could not earn a profit because of price competition and substitute goods. The synthetic fabric industry, through innovative chemistry and manufacturing processes used primarily in laboratories and plants overseas, created man-made fibers that had many qualities that made them superior to cotton. This forced the cotton industry to compete by trying to reduce costs. Inefficiencies in production, however, made cotton more expensive than necessary.

For example, textile producers were forced to blend polyester into their fabrics solely to increase fabric strength. Furthermore, they had to use far more cotton than otherwise would be necessary in order to compensate for shrinkage. These processes generated additional costs that reduced the U.S. cotton industry's profit.

If less favorable properties such as shrinkage could be cost-effectively reduced, however, cotton could regain its competitive advantage. For example, in fleece products alone, 25 percent less cotton per garment could be used. Consequently, the industry spent significant time and money researching ways to

incorporate synthetic fabric properties into cotton plants. As of 1994, however, there were no promising methods of eliminating cotton's unfavorable characteristics.

Synthetic Properties Could Be Introduced Into Pure Cotton

In 1994, the Middleton, Wisconsin-based agricultural products company, Agracetus, showed through initial research that it was theoretically possible to genetically engineer a set of traits into cotton plants that could revolutionize cotton production, capture additional global market share, and lift prices above commodity levels. If the company could translate the biotechnical theory into practice within a prototype cotton plant, the result could be a commercial crop with greater fiber strength, reduced shrinkage, enhanced wrinkle-resistance, better thermal properties (such as an ability to breathe in the summer and retain heat in the winter), and superior dye binding.

Agracetus focused on the genetic engineering steps necessary to modify cotton fiber.

If successful, Agracetus envisioned a new generation of cotton created exclusively by U.S. companies that would increase export opportunities for cotton farmers, mills, and textile manufacturers. Initial projections showed potential sales of more than \$1 billion between 2000 and 2005, assuming technical success and rapid market penetration.

Agracetus Seeks Funding for Genetic Engineering Research

Agracetus' strategic plan required that the company devote nearly all its available resources to cotton fiber products in order to develop a first-generation product known as Fiber #8802. The company had enough resources to fund the necessary studies on gene identification in cotton fibers and plant transformation through gene insertion. Ideally, Agracetus executives wanted Fiber #8802 to have additional properties. Specifically, the fiber should have the correct number and types of genes to improve the cotton's dyeability, dimensional stability (reduced incidences of wrinkling

and shrinking), heat-withstanding ability, and stain-repelling properties. All of these qualities were necessary for the commercial acceptance of a premium product.

The technical risk involved in incorporating these characteristics into Fiber #8802, however, was too high for Agracetus to undertake. Company researchers felt strongly that research was necessary in order to quickly advance the cotton industry to the point where it could capture additional global market share. The researchers received management's approval to search for additional funding to enable this research. Agracetus approached trade groups within the U.S. cotton industry for resources, but because of the depressed profitability of the industry, funds were not available for a project with such a high technical risk.

After failing to obtain funds from other sources, Agracetus submitted a proposal to ATP and was awarded \$1 million to carry out their genetic engineering research. This research was essential to get the leaders in the industry to focus on the technical roadblocks to biopolymer development that had hindered commercialization for years.

Ambitious Research Goals Require Collaboration

During the ATP-funded project, Agracetus focused on the genetic engineering steps necessary to modify cotton fiber. Internal research completed prior to the start of this project suggested that two bacterial genes were necessary for cotton to form polyester-like compounds such as poly-3-hydroxybutyric acid (PHB). The primary technical goal of the project was to get PHB levels in cotton up to the point where the fiber took on the favorable qualities of synthetics while retaining the superior thermal characteristics of pure cotton.

Agracetus envisioned a new generation of cotton created exclusively by U.S. companies.

In order to test whether PHB levels resulted in the appropriate mix of cotton and synthetic traits, Agracetus relied on tests from the Cotton Incorporated Research Center in Raleigh, North Carolina; the Starlab Specialty

Testing and Research Laboratory in Knoxville, Tennessee; and the International Textile Center of Texas Tech University in Lubbock, Texas.

Biopolymer Concentration in Prototype too Low for Commercialization

By the end of the ATP-funded project in 1998, Agracetus had produced a prototype plant and had it tested by the three research laboratories. Agracetus achieved a major technical milestone by developing a prototype plant with elevated levels of PHB. Initial testing showed that, while the fiber had many of the necessary properties for commercial applications, a major problem remained. In order to achieve the desired synthetic-like properties within the cotton fibers, the biopolymer added to the cotton plant would have to be increased five- to tenfold. Research conducted during the course of the ATP project showed that this increase would be extraordinarily difficult to achieve because when the PHB levels increased that significantly, other favorable traits were "crowded out," reducing the plant's commercial viability.

Given the continued risk and relatively small likelihood of success, Agracetus executives decided not to conduct additional research and development after the end of the project. Although no products resulted from this project, Agracetus' ATP-funded research accelerated the pace of research in biopolymers at a crucial time when the industry faced significant pressure from overseas competitors.

Agracetus was acquired by Monsanto Company in 1996. During the following year, corporate priorities shifted, and no further research or development of Agracetus' proposed technology has occurred since the end of the grant.

Agracetus Shares Project Knowledge to Help U.S. Cotton Industry

Agracetus researchers took a number of steps to publicize the results of their ATP-funded research in order to assist the U.S. cotton industry. Agracetus scientists wrote articles on the technology that appeared in professional journals, company representatives delivered presentations at conferences, and the popular press reported on the technology

several times. Even though Agracetus is not pursuing further commercialization, sequencing the cotton genome is the subject of a number of domestic and international research projects.

Conclusion

In 1995, with the help of ATP funding, Agracetus started an aggressive research plan to determine if it was possible to incorporate the most beneficial properties of synthetic fabric into natural cotton through genetic engineering. The results of a successful project could have increased U.S. market share and annual sales by more than \$200 million. By 1998, when the project ended, Agracetus researchers were able to use genetic engineering to introduce a biopolymer into cotton plants. The biopolymer concentration, however, would have to be increased 5 to 10 times the achieved level in order to be commercially viable. However, the company disseminated its knowledge from the project throughout the industry through professional publications, the popular press, and company presentations.

PROJECT HIGHLIGHTS

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Project Title: Biopolymers to Give Cotton Fibers Synthetic-Like Qualities (Transgenic Cotton Fiber with Polyester Qualities Via Biopolymer Genes)

Project: To develop a genetically engineered version of cotton that outperforms standard cotton fibers in such properties as dyeability, strength, resistance to wrinkling, and shrinkage.

Duration: 2/1/1995-1/31/1998

ATP Number: 94-01-0074

Funding (in thousands):

ATP Final Cost	\$1,018	54%
Participant Final Cost	<u>870</u>	46%
Total	\$1,888	

Accomplishments: Through its aggressive research plan, Agracetus advanced the industry's knowledge of biopolymers in cotton by two years. In addition, the company produced a prototype plant with elevated levels of poly-3-hydroxybuteric acid (PHB). Although the PHB concentration was not high enough for commercialization, simply raising the PHB level at all represented a technical achievement.

Agracetus disseminated its project knowledge through a variety of media. Company employees published papers in 10 professional journals and publications. Agracetus representatives gave presentations at five conferences in the United States and around the world. The popular press, which included *Knight Ridder*, *Associated Press*, *The Wall Street Journal*, and *USA Today*, also reported on Agracetus' project more than 20 times.

Commercialization Status: Due to the difficulty in attaining high enough PHB levels in the cotton fibers without "crowding out" the fibers' favorable traits, no commercialization efforts resulted from this ATP-funded research.

Outlook: Because no products will result from this project unless another company begins research after the cotton genome is sequenced, the outlook for the technology is poor.

Composite Performance Score: No Stars

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